The Electron Cloud

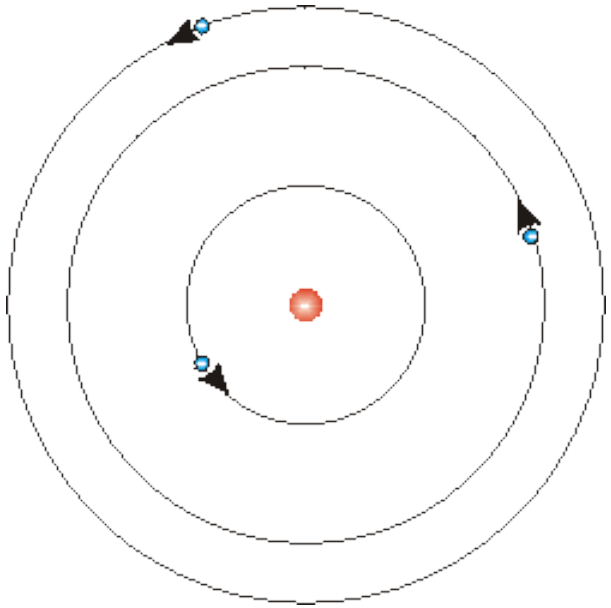
- Here is what we know about the electron cloud:
  - It contains the subatomic particles called electrons
  - This area accounts for most of the volume of the atom (empty space)
  - These electrons have a negative charge
  - Finding electrons in the cloud is impossible

Bohr's Model of the Atom

1. Bohr pictured the atom as having electrons in well ***fixed paths or orbits***
2. when electrons are in orbits, they have fixed amounts of energy
3. total energy of an electron increases as the distance from the nucleus increases

   (orbit is further out from nucleus)

Bohr's Model of the Atom



What happens when electrons move?

- energy is released or absorbed by electrons when they move in the electron cloud from different levels.
  - This energy is called electromagnetic radiation
  - It comes in various forms from radio waves to cosmic rays

Electromagnetic Energy

- Electromagnetic energy
  - defined as a form of energy that exhibits wavelike behavior as it travels through space
  - speed in a vacuum is 3×10^8 m/s
  - The measurable properties are:
    - Wavelength -distance between corresponding points on adjacent waves
    - frequency- is the number of waves that pass given point in a specific amount of time (usually 1 second)

Electromagnetic Energy

- The math relationship between frequency and wavelength is:
  - $c = \nu (\lambda)$
  - where c is the speed of light,
  - λ is the wavelength
  - ν is the frequency
  - a closer look at this equation reveals that wavelength times frequency is a constant c.

Electromagnetic Energy

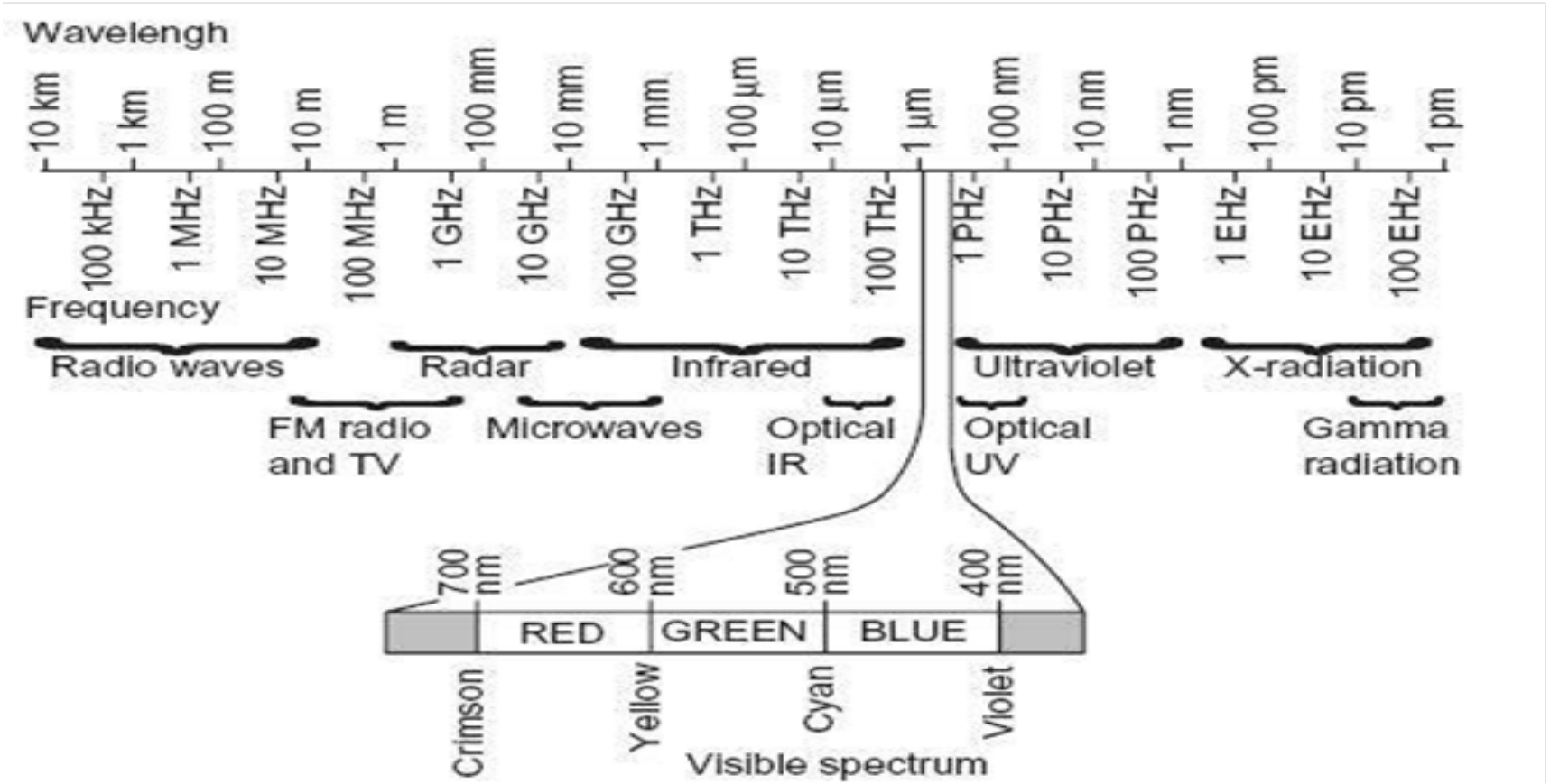
– other relationships are:

- wavelength is inversely proportional to the frequency
- as the ***wavelength*** of electromagnetic energy ***decreases,*** the ***frequency increases***.
- also as the ***wavelength*** of the energy ***increases***, the ***frequency decreases.***

Electromagnetic Energy

- short wavelengths have high frequencies
- long wavelength have low frequencies
- visible light is what you can see
  - red is long wave and low energy
  - violet is short wave and high energy
  - remember R O Y G B I V

The Electromagnetic Spectrum



Energy packets

New ideas about energy:

- In 1900, German Physicist Max Planck proposed that the energy comes in small very specific amounts not one continuous wave of energy
- Planck called these chunks of energy *quanta*

Energy Packets

- a quantum is a finite amount of energy that can be gained or lost by an atom.
- a photon is a quantum of light
- This leads to a second equation(Planck's equation)
  - $E = hf$ where E is energy, h is called Planck's constant which is 6.26×10^{-34} joule-seconds and f is the frequency
  - this means that **energy** is **directly proportional** to **frequency**!!!!!
  - and when frequency increases so does the energy of the radiation

Sometimes it's a particle and sometimes it's a wave.

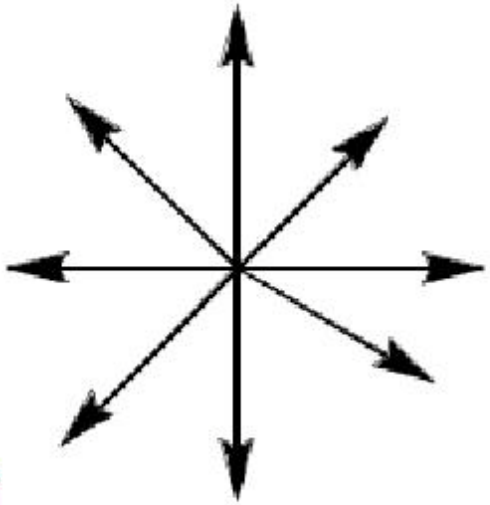
- Up to now scientists thought that light always acted like a wave.
- But it turns out that some frequencies can act like particles.

- This phenomenon is called the duality of light

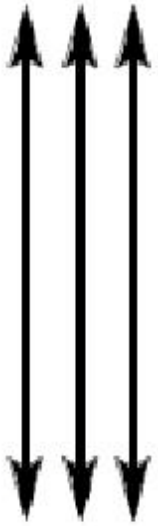
Dual Nature of Light

- proof of light acting like a wave is found in wave interference

  Example:polarized sunglasses only let light waves in a single direction through the material.



Ordinary light



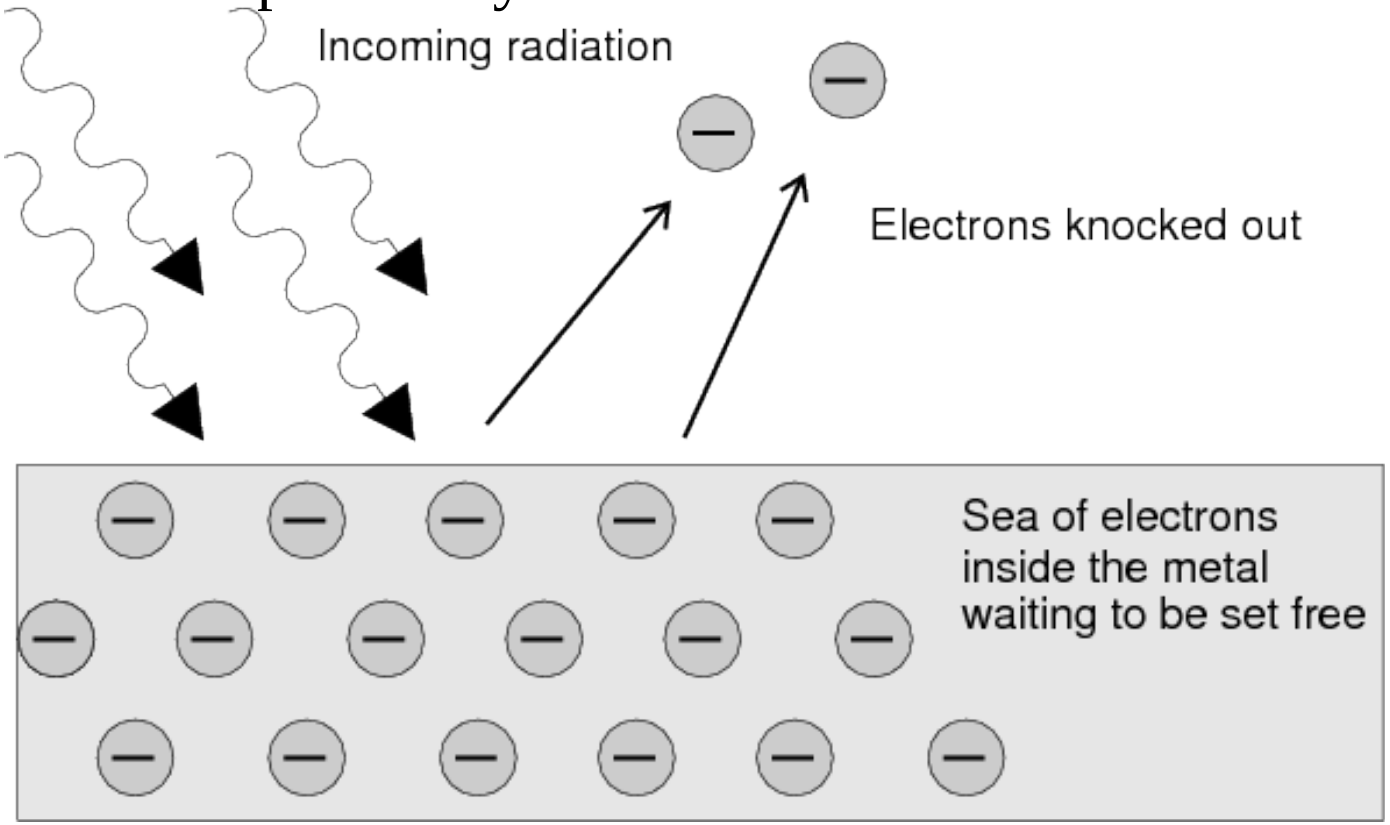
Plane Polarized Light

Dual Nature of Light

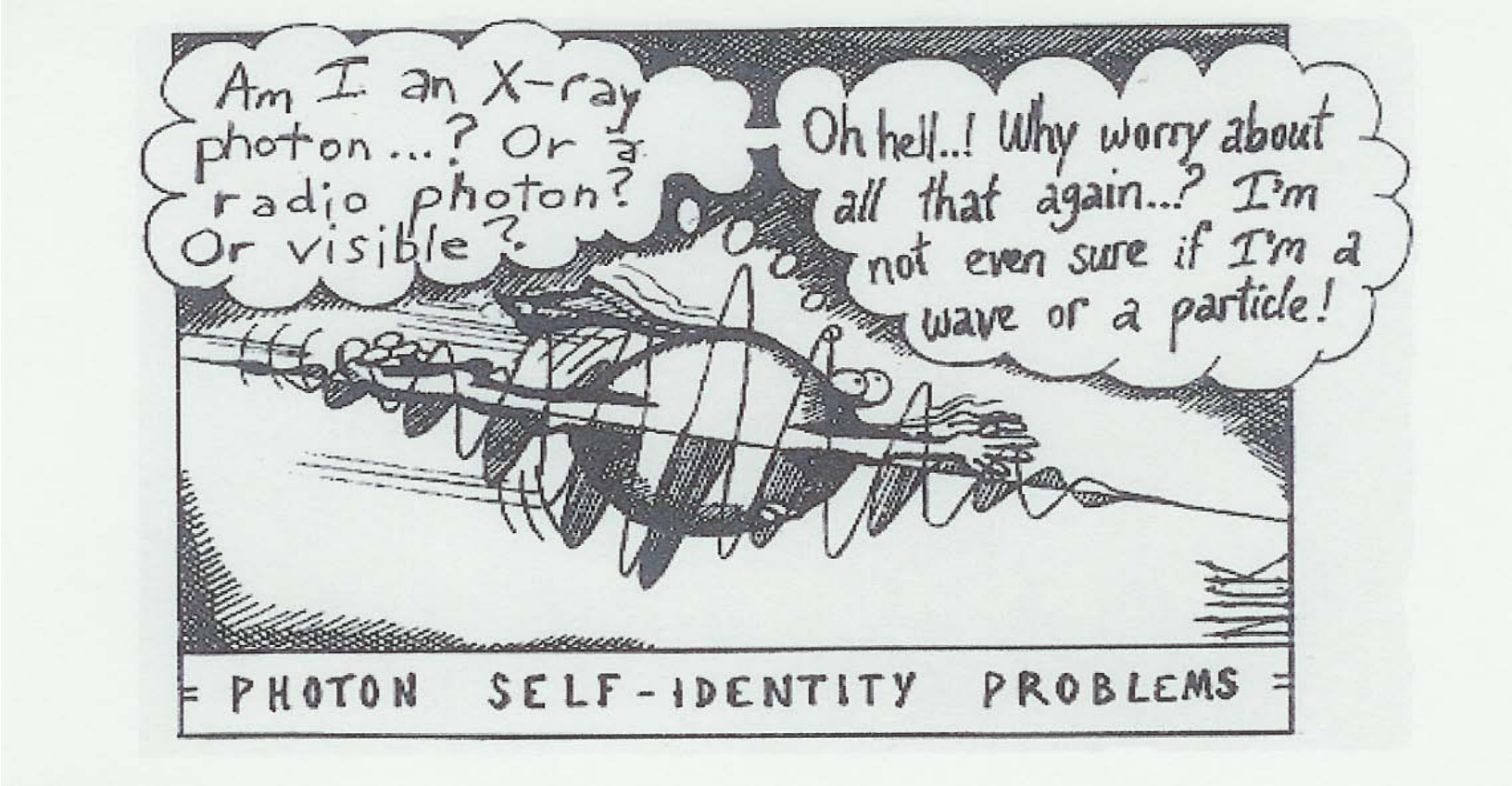
- proof that light acts as a particle is found in the photoelectric affect which occurs when light strikes certain metals and electrons are knocked out (usually violet light).

Photoelectric effect

- This was explained by Einstein.



Could this confusion happen in your laboratory?

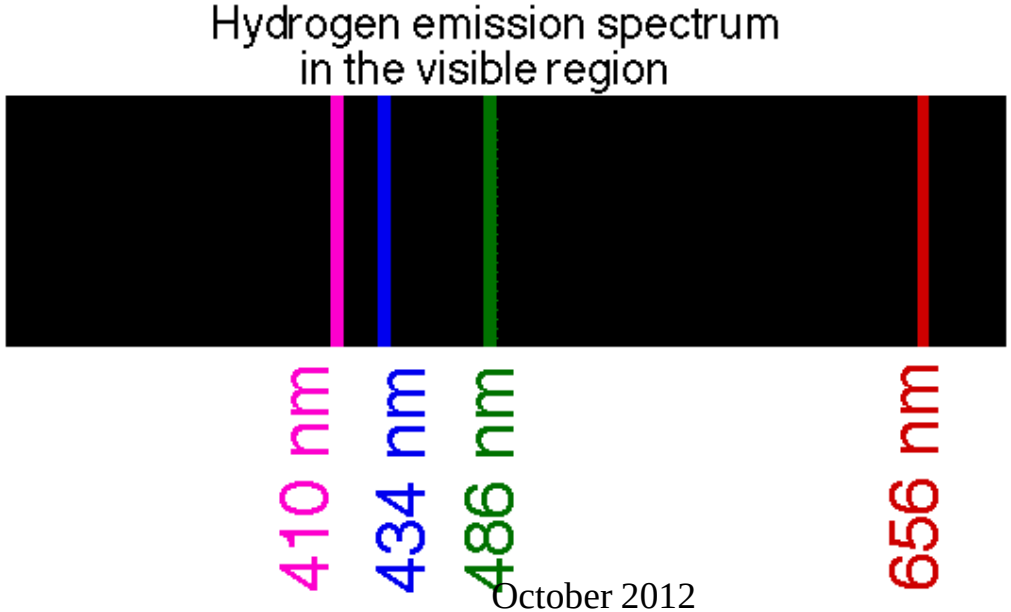


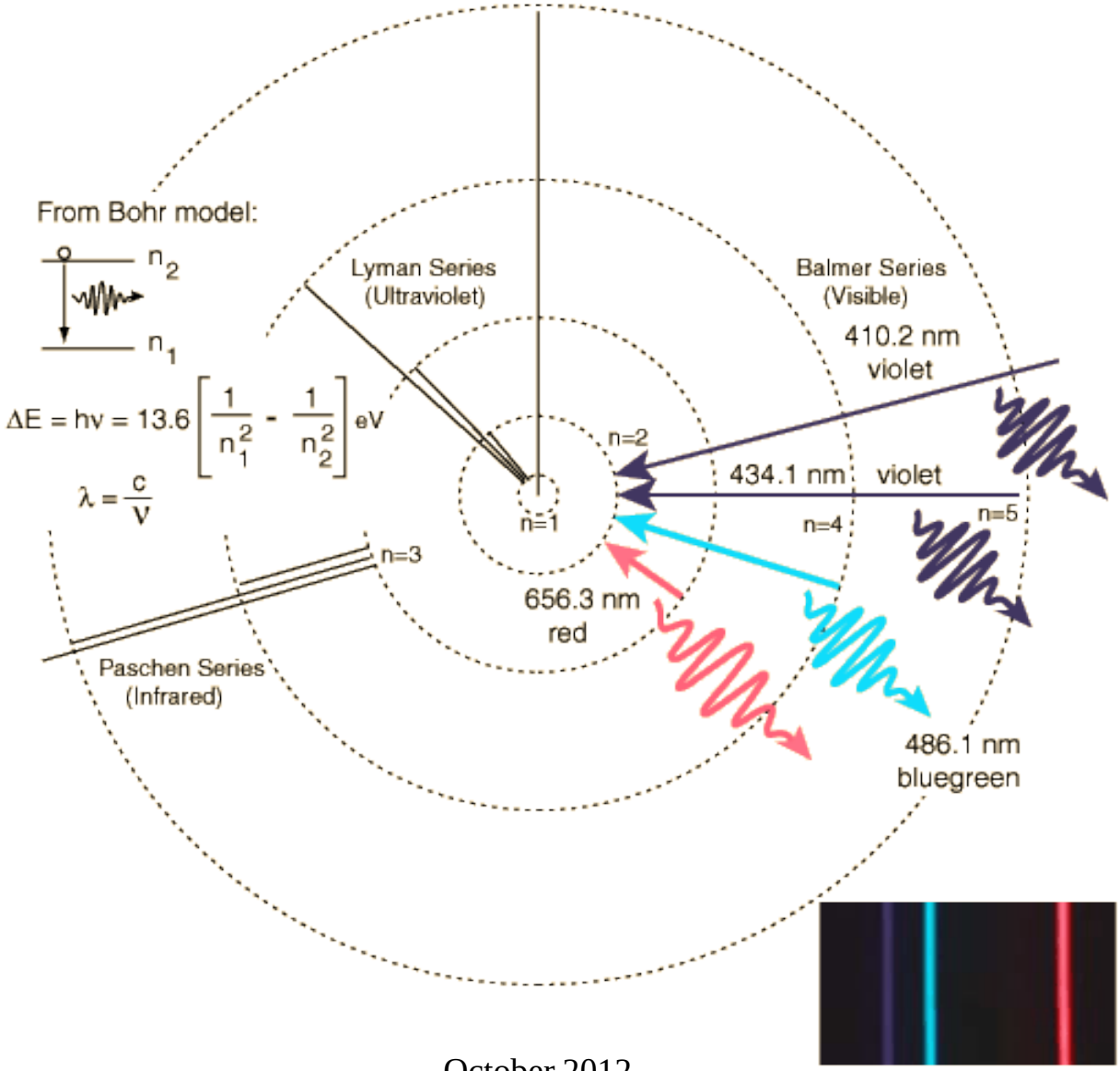
What you see

- The human eye can only detect a small region of the electromagnetic spectrum.
  - This is called the **visible spectrum**.
- We will use this area of the EMR spectrum to identify elements.

Bohr and the hydrogen spectra

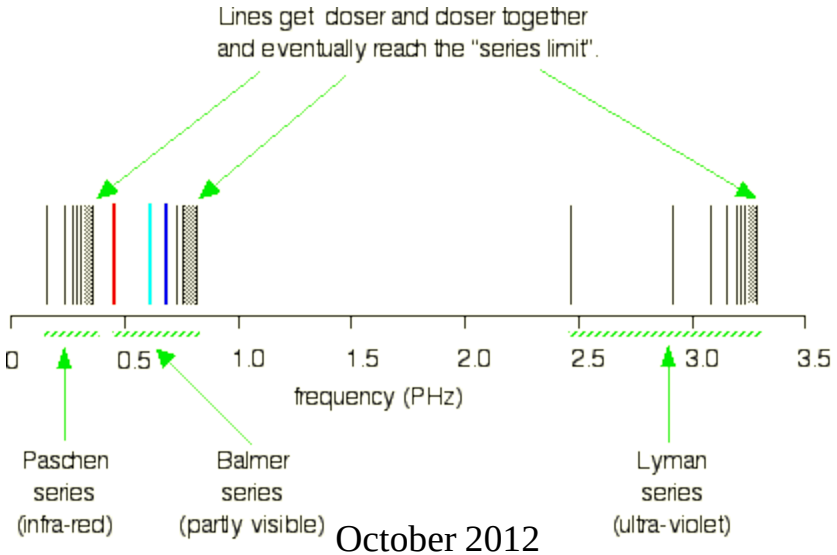
- Bohr explained the small bright spectral lines came from electrons that were going from higher orbits to lower orbits.




From Bohr model:
n_2
n_1
$\Delta E = h\nu = 13.6\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ eV
$\lambda = \frac{c}{\nu}$
Lyman Series
(Ultraviolet)
Balmer Series
(Visible)
410.2 nm
violet
434.1 nm
violet
656.3 nm
red
486.1 nm
bluegreen
Paschen Series
(Infrared)
n=1
n=2
n=3
n=4
n=5

Bohr didn't have all of the answers.

- Bohr could not explain some of the spectral lines we cannot see. These were in the infrared and ultraviolet regions of the EMR which we as humans cannot see.



Bohr adds the quantum idea

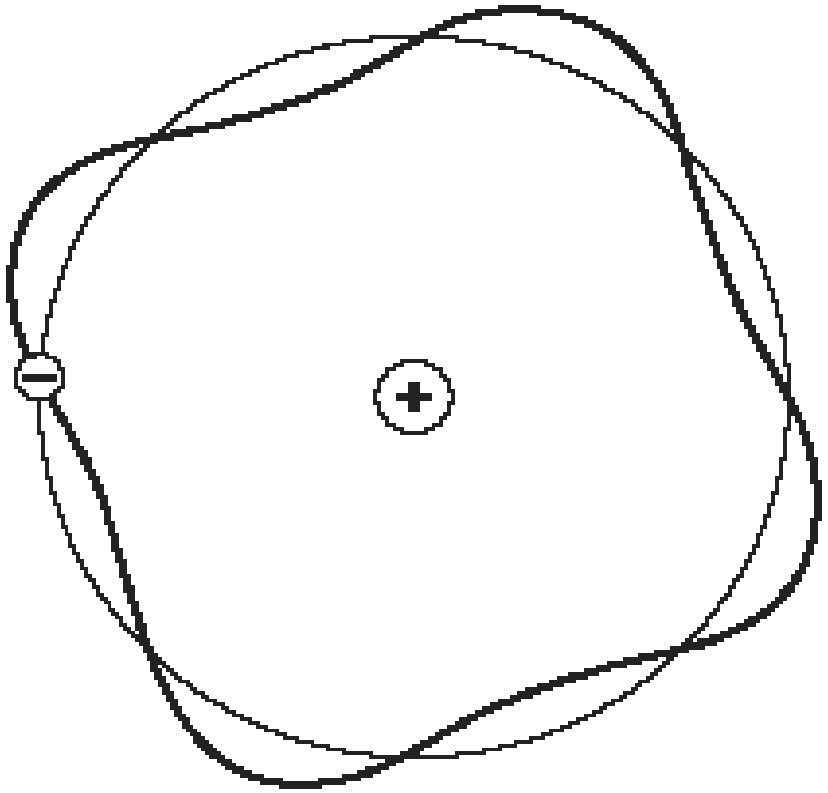
- Bohr reasoned that the energy coming from electrons moving down from higher levels to lower levels in an atom were:
  - Going from excited state to ground state
  - Releasing energy in these small packets called quanta (photons)

New Idea about the electron

- de Broglie reasoned if light acts like a wave, then that electrons can act like waves.

- this was consistent with Bohr's proposed quantized electron orbits

- This is how de Broglie saw the electron wave



Quantum Model of the Atom

- 1. The location of the electron cannot be determined exactly.
  - This brings us to the ***Heisenberg Uncertainty Principle*** that states that you cannot determine the location of and the momentum of an electron at the same time.

- 2. The electrons are in energy levels.
  - As the levels increase in energy the distance from the nucleus increases
  - In other words electrons with more energy are further from the nucleus.
  - The energy levels are also known as energy shells.

Quantum Model of the Atom

3. The mathematics describes for us a region of space around the nucleus where electrons most likely be found.

These are 3-D regions that are called orbitals.
Atomic orbitals to be exact.

The math equation looks like this:

The Schrødinger Equation is the fundamental equation of quantum physics and can be expressed as follows:

$$H\psi = E\psi$$

Quantum Model of the Atom

- This is a huge equation when all the stuff is put in:
  - For the hydrogen atom (1 e^{-1}) the answer looks like this:

$$\psi(r,\theta,\phi) = R(r)P(\theta)F(\phi)$$

Principal Quantum #

Orbital quantum #

Magnetic quantum #

Quantum Model of the Atom

- 4.The math equations describe electrons in what are known as quantum numbers. There are 4 numbers:

- a. Principal Quantum (n) number indicates the main energy levels around the nucleus. n = 1,2,3,4,5,6,7….

- b. Orbital quantum number (l) identifies the shape of the orbital.

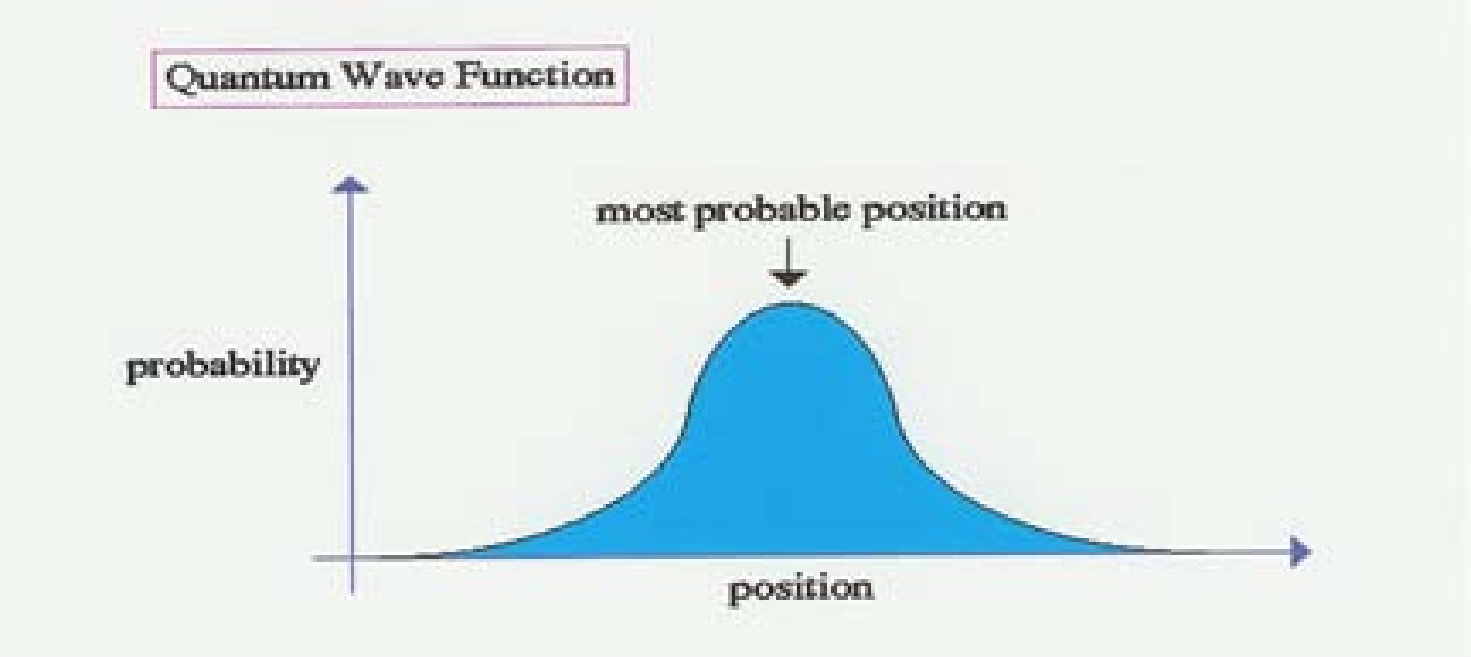
1. 0 = s orbital
2. 1= p orbital
3. 2 = d orbital
4. 3 = f orbital

Quantum Model of the Atom

- c. Magnetic quantum number(m) shows the orientation of the atomic orbital around the X-Y-Z axis. (3-D)

- d. Spin quantum number (s) shows the spin (rotation) of the electron on the axis. Has only two possible values + ½ or – ½.

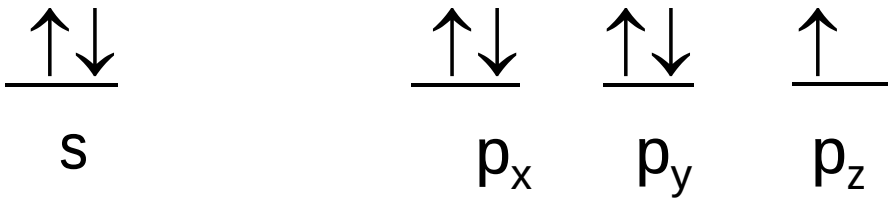
Where an electron might be found



Electron Configuration

- Assigning electron configuration is assigning addresses to electrons according to the amount of energy the electron has.
- There are 3 ways to show electron addresses:
  - 1) electron configuration- shows principal energy level, orbital shape, & # of electrons
    - Example: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

Electron Configuration

- 2) orbital notation –uses arrows and lines to show electrons usually in the outermost electron orbitals
  - Example: 

Electron Configuration

- 3) dot notation (also called Lewis dot)-uses the symbol of the element and dots to show the the outermost electrons.
  - Example: $\cdot H$ $\cdot \dot{H}e$

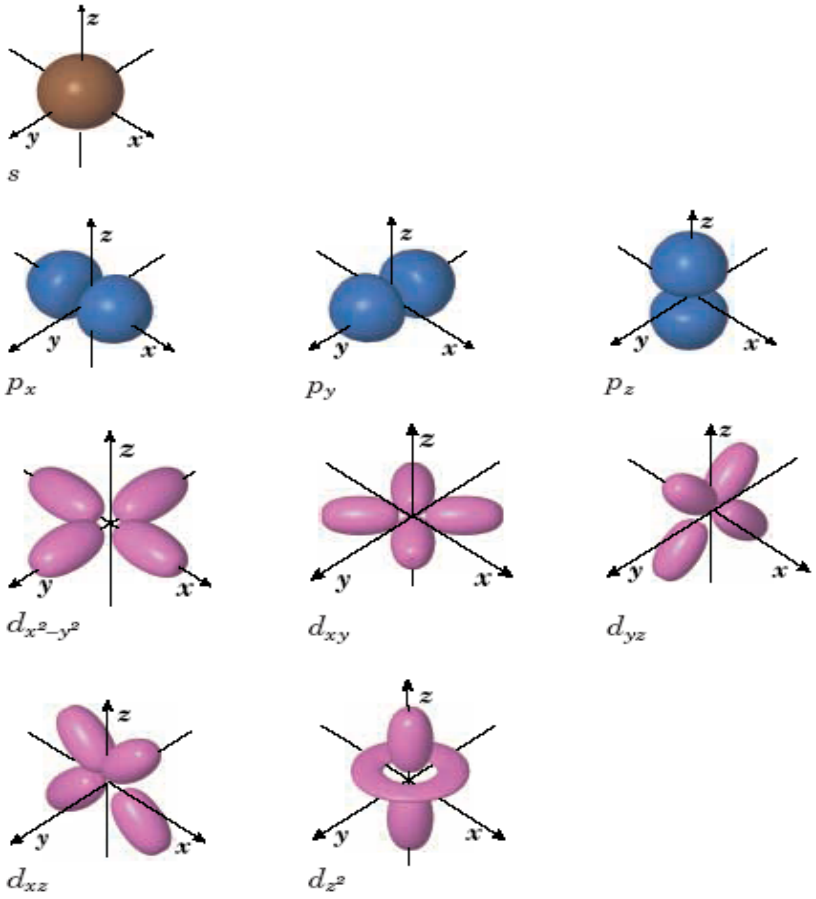
Electron Configuration Rules

- From quantum mechanics we have a probable location of the electrons in an atom.
- The four quantum numbers describe an electron.
  - The **Pauli exclusion principle** says that no two electrons can have the same exact quantum numbers. This means that they cannot be in the exact same place at the exact same time.

Location of electrons

- Now, where are they?
  - Well we know that they are in regions called atomic orbitals.
  - These 3-D regions of space are probable locations of electrons.
  - Any one atomic orbital can only hold 2 electrons.
  - also know that the orbitals have shapes and are oriented around the X, Y, and Z-axis.

Shapes of *s*, *p*, and *d* Orbitals



Suborbitals

- Atomic orbitals are subdivided into suborbitals. This is how it looks:

orbitals	suborbitals	# electrons	Shape
s	None	2	sphere
p	3	6	dumbbell
d	5	10	multiple
f	7	14	Don't go there
g	9	18	Too complex
h	11	22	No clue

Aufbau principle

- **Aufbau principle**
- When electrons are added to the outside of a nucleus they will go into the orbital with the lowest energy. You cannot add outside in.

Hund's rule

- **Hund's rule**
  - Orbitals of equal energy are each occupied by one electron before any one orbital is occupied by a second electron and all electrons in a singly occupied orbital must have the same spin (must be going the same way as the others).
  - Explanation: when putting electrons in the p-orbitals there must be one electron in p_x, p_y and p_z before any of the others can have get a second electron.

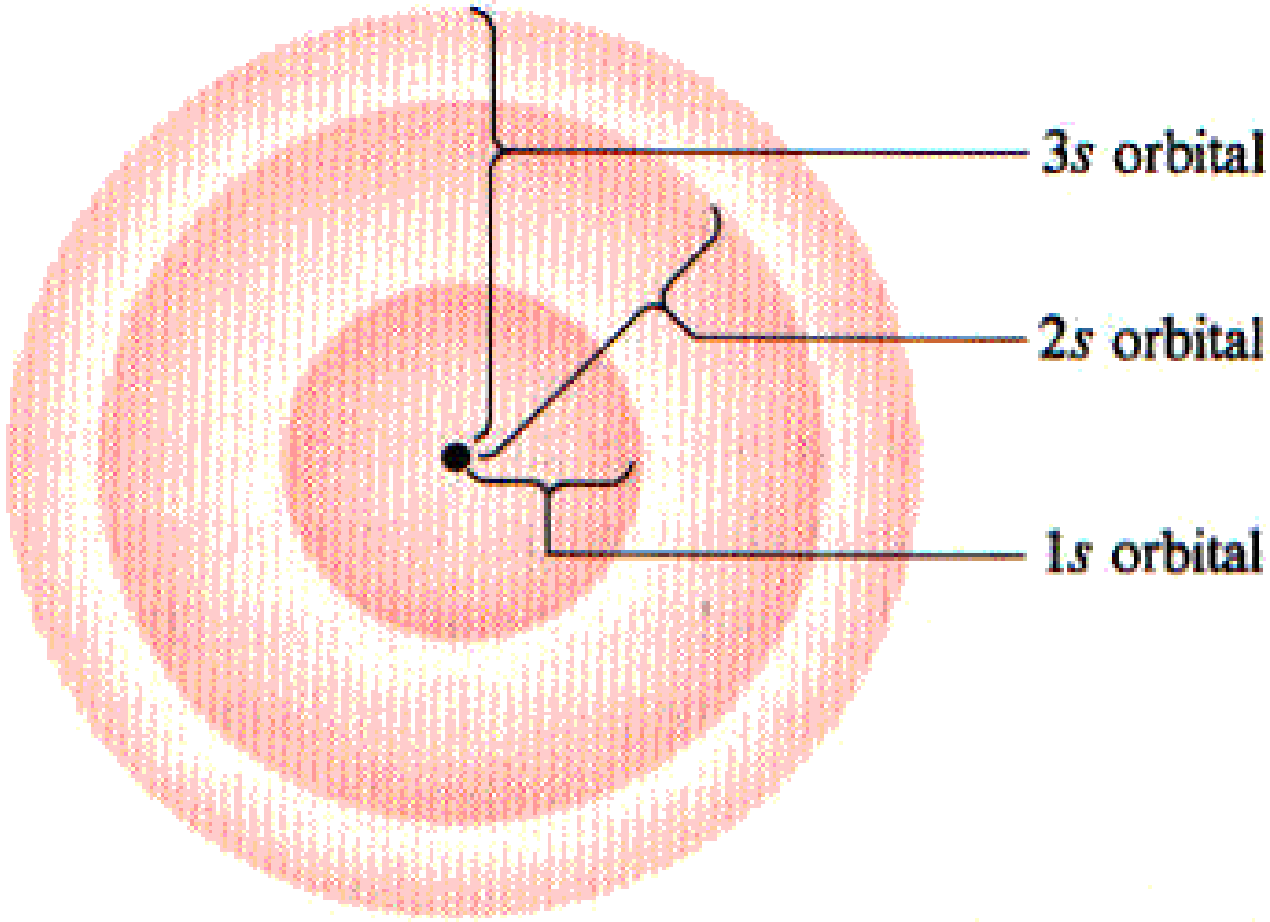
Following the flow chart

- When writing electron configuration you will need to follow the order of fill chart.
- This is a systematic way of arranging the electrons.
- You will need to know how many electrons are in each of the orbitals.
- The configuration you write may not match what is in Chemistry textbooks because electrons in more complex atoms will move to create more stable configurations based on the lowest possible energy.

Following the flow chart

– Remember that the most stable electron configuration is that of the noble gases which all have ns^2np^6 configuration.

s orbital shapes



p orbital shapes